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SECTORAL TECHNOLOGY STRATEGY SERIES

No 3

The Canadian Iron and Steel Sector

SECTORAL TECHNOLOGY STRATEGY SERIES

NO. 3 THE CANADIAN IRON AND STEEL SECTOR

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Highlights

- During most of the past 20 years, the Canadian iron and steel industry grew and prospered. The large companies were driven by a business strategy of building capacity only to meet "base-load" demand, which seemed appropriate for the economic environment in which they operated.

- Because of imported technology, raw materials that were relatively low cost and good quality, low energy costs, and a skilled labour force, the industry has long been competitive with industries in other countries. It has ably executed an "adopt and adapt" technology strategy, one that is necessary but no longer sufficient to achieve longer term success.

- By late 1990 and early 1991, financial conditions had deteriorated and the two largest integrated producers, which accounted for about 70 per cent of total Canadian output, had sustained large losses. The conditions reflected more than a normal business downturn and presented a fundamental problem for these major firms. The mini-mills that produce most of the remaining 30 per cent of output are closer to profitability, but their domestic growth prospects are limited.

- Major steel-process R&D requires a large and long-term investment. Canadian steel firms have followed a strategy of technology purchase, supported by limited R&D for minor adaptations and improvements. Canadian firms have pioneered a few notable innovations. In international comparisons, the Canadian steel-industry R&D/sales ratio is very low, less than half the ratio in leading European countries and the U.S., and one-sixth that of Japan.

- The Canadian industry has focused largely on commodity steel. Firms have developed few differentiated and sophisticated steel products, in part because they have not faced as intense competition and as demanding customers as the Japanese steel industry. The focus on commodity steel makes the industry particularly vulnerable to adverse currency swings.

- In the past 20 years, Japan has emerged as the major player in the global iron and steel industry. Japanese companies have invested heavily in both process and product technology to be cost competitive and to develop high-quality steels for different end-use markets.

- Japanese steel companies are now investing heavily in research into materials other than steels, using steel revenues to finance that research. They are diversifying and becoming materials companies, rather than simply steel companies. More than 50 per cent of R&D by the large Japanese steelmakers is now on non-steel products or processes.

- Following the recession in the early 1980s, the U.S. industry, which was not very advanced technologically, was forced to restructure massively, shutting down antiquated mills, reinvesting in the survivors, and operating at one stage behind import quotas. Joint ventures with Japanese companies provided access to Japanese technology, in exchange for equity and/or a share of the profits, and helped raise the level of U.S. competitiveness, threatening the level of Canadian exports to the United States and rapidly increasing U.S. steel imports into Canada.

- The leading Canadian steel companies now face few opportunities to increase significantly their R&D levels to any degree unless they merge or engage in joint ventures, possibly with other

Canadian materials companies and selected end-users of steel, such as auto-parts manufacturers and construction companies.

Background to the Sectoral Technology Strategy Series

In the emerging "new" economy of the 1990s, successful high-value businesses in advanced nations are being driven by innovation, propelled by spending on new products and processes. Their business strategies centre increasingly on specialized knowledge and skill in finding the right "fit" between their unique blend of core technologies and particular markets.

Where does Canada stand in this rapidly evolving new environment of changing linkages and relationships? The poor innovative capacity of Canadian industry has long been a concern of the Science Council of Canada, going back to its 1971 report *Innovation in a Cold Climate*. The Council re-emphasized this concern in 1988. It focused its attention on the potential for action at a sectoral level in its statement *A Sectoral Approach to Innovation*. It argued:

> There is growing recognition by industry and government in Canada of the key role played by technology and R&D in domestic and international competition. The Science Council considers that it is primarily the responsibility of industries to raise the degree of domestic technological sophistication and the level of R&D. Nevertheless, governments can help business to sustain long-term competitiveness both by building partnerships with individual firms and by generating consensus on the formulation of innovation strategies for the various industrial sectors. The intent is not for government to tell business what to do, but to facilitate business cooperation in a process of self-help. The process of building consensus on a strategy for a particular sector will involve close and on-going consultation with industries about the current role of technology and R&D in the sector, the opportunities foreseen, and the nature of the sources, stimuli, and forms of technological innovation. Obviously, to be successful, separate innovation strategies will be needed for each sector. The Science Council hopes that the process of building consensus will generate commitment and collective will concerning priorities, areas for cooperation, and agenda for action.

This statement proved to be an important step in the path that subsequently led the Council to undertake a major Sectoral Technology Strategy project.

In 1989, Industry, Science and Technology Canada, at a time of heightened concern for the state of Canadian competitiveness and serious questioning about the low level of Canada's gross expenditures on research and development as measured against other advanced countries, agreed to provide the main funding for this project. It also stipulated the selection of sectors on which it would like the project to focus.

Each report in this Sectoral Technology Strategy Series draws in part upon analyses commissioned by the Science Council of Canada from contractors, designed to reveal the key dynamics driving technological innovation in the sector and influencing company technology strategies. Each report has also benefited considerably from the comments and advice submitted by the many external reviewers from business, universities, and government, who are recognized in the Acknowledgements.

Commentary on the Sectoral Technology Strategy Series and R&D Targets

The Sectoral Technology Strategy Series has analysed 15 Canadian sectors. On the basis of this experience, the Science Council of Canada makes the following points with regard to Canadian R&D performance and the issue of setting sectoral R&D targets.

- Canadian firms, when grouped by sectors, generally perform much less R&D than their trade competitors. Using the indicator of R&D as a percentage of sales, Canadian firms undertake R&D at a rate about one-third to one-half the rate of their leading international sectoral competitors. The notable exception among those sectors analysed is telecommunications.

- In some product lines or specific technologies certain absolute threshold levels of R&D and capital investment must be reached if the effort is to be considered to have a chance of making a commercial payback. High thresholds are apparent in some parts of sectors such as telecommunications (central office switches), automotive parts ("Tier 1" supplier status), oil and gas (reformulated gasoline standards by refineries), and electronics (integrated circuit foundry). Such absolute thresholds cannot be clearly expressed as a percentage of sales.

- The reasons for the lower level of R&D spending by firms in most of the 15 Canadian sectors are: choice of business and technology strategy (which, in part, leave Canadian companies as essentially non-participants in many higher value-adding segments); the relatively small size of Canadian firms; the high absolute thresholds of R&D expenditure required to be a meaningful player, especially for innovative technology strategies; and the degree of foreign ownership of Canadian firms (especially important in the case of the automotive vehicles and parts sectors).

- The lack of R&D relative to other countries affects Canadian competitiveness, but it is only one of many factors, such as capital and labour costs, quality design, good marketing, and management, that interact to affect overall competitiveness. Nevertheless, the contribution of R&D, or more precisely, technology-based innovation, is becoming more pronounced throughout the global economy and Canada continues to fall behind. The low level of R&D is especially detrimental to the capacity of Canadian resource-based sectors to compete with higher-value, differentiated products, leaving them vulnerable to adverse shifts in costs beyond their control, such as a higher exchange rate.

- Major potential does exist for Canadian industry to make additional R&D investments. However, fulfilling this potential depends heavily on the vision and capability of management to make strategic use of technology, to speed the firms' innovation process, to work more closely with suppliers and "demanding customers" all the way to the end of the product chain, and to build core capabilities in incremental innovation and R&D. Canadian firms have not yet fully grasped the implications of the emerging new "lean enterprise" or "agile producer" strategy. To follow this new strategy involves seeking to offer maximum value to customers. It requires integrating the skills base of a knowledgeable workforce with flexible management structures that stimulate cooperative initiatives within and between firms to match customer needs.

- The dominant technology strategies being followed by Canadian firms in these sectors are of adopt and adapt. Innovation technology strategies are not very extensive (telecommunications is again an exception) and hardly any firms focus on breakthrough strategies to enhance competitiveness. Overall, these 15 sectors show little attempt at diversification out of existing product lines as opposed to making such products more efficiently.

- Governments can set sectoral R&D targets in the hope of stimulating enhanced industrial performance, shifts in business strategy, and greater commitment by the private sector to R&D. However, private sector R&D is only meaningfully undertaken in conjunction with a full complement of associated private and public sector actions ranging from improved design and production to finance and marketing. Doing more R&D will not be productive unless linked to a broader corporate technology strategy that is carefully designed to support the firm's business objectives. Otherwise, the corporation cannot, and will not, marshal the complementary investments required to reap the benefits of the R&D. It is the firm that must commit R&D resources.

- Setting sectoral R&D targets becomes more difficult as the boundaries between sectors are breaking down, through technological advances, regulatory change, and firm restructuring. Larger and more diversified firms that dominate modern industrial R&D perform R&D that might be allocated to any of several sectors. Examples include the textiles and materials R&D performed by large Japanese steel firms, the electronics R&D by automotive-vehicle firms, and the software R&D by telecommunications firms. Canadian governments have quite correctly encouraged higher levels of industrial R&D in Canada. In view of the rapid pace of scientific advances and technological change, plus the role of system interdependencies and synergies between technologies, setting R&D targets does not appear to be a task warranting the intensive effort, cooperation, and, ultimately, commitment that would be required by federal and provincial governments and private sector organizations.

List of Sectoral Technology Strategy Series Reports

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No. 2 The Canadian Automotive-Parts Sector
No. 3 The Canadian Iron and Steel Sector
No. 4 The Canadian Automotive-Vehicle Sector
No. 5 The Canadian Oil and Gas Sector
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No. 9 The Canadian Forest-Products Sector
No. 10 The Canadian Machinery Sector
No. 11 The Canadian Food and Beverage Sector
No. 12 The Canadian Electric-Power Sector
No. 13 The Canadian Consulting-Engineering Sector
No. 14 The Canadian Electronics Sector
No. 15 The Canadian Computer Software and Services Sector

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Introduction

"Caught in a rut," "deep in debt, with payments growing beyond the company's ability to carry them alone," "problem plagued," "selling major assets and closing unprofitable operations," "a 'buy and operate' mentality, highly vulnerable to innovative new approaches," "a grim future," "a showcase for everything wrong in Canadian industry" — these are some disturbing recent comments about Canada's steel sector and its leading companies. The financial condition of the sector, though reasonable through the 1980s, has deteriorated rapidly since, even though production and shipments during most of the decade kept pace with world steel production and despite unprecedented capital expenditures on modernization. The leading firms in this sector now face serious concerns about how to adjust and align their business and technology strategies.

The main objectives of this report are to indicate the technology strategies of these firms, to show how the sector performs in R&D compared with its main trade competitors, to outline the major reasons for the differences in R&D behaviour, and to explain how these differences affect the competitiveness of Canadian firms.

The Global Steel Sector

World Production

Iron and steel have historically been the backbone of industrial economies and the foundation of other key economic sectors, such as construction, shipbuilding, and transportation. As these sectors expanded, steel producers could count on steadily growing demand. This is no longer true. Although overall world steel production is growing, steelmakers in the advanced industrial nations are in the midst of a long-term decline in demand, production, and profitability. This decline began in the late 1970s and accelerated during the early 1980s. Despite some cyclical upturns, the trend shows no signs of abating. The principal causes are shrinking domestic demand for steel in the developed nations, development of new products that can reduce the steel content of goods such as cars and construction materials, and competition from steel producers in newly industrialized countries with lower labour costs.

Table 1 shows production in the major steel-producing countries for three significant years: 1979, a cyclical peak; 1982, a cyclical trough with the lowest total world production for the 1980s; and 1988, another peak and the first year in which world production exceeded the 1979 level. The gross output figures presented here are based on published data on production. Further data on actual shipments, product mix, and product-specific prices would tell more about the competitiveness of the steel industry in the 13 nations.

The oil crisis of the 1970s led to rapidly rising inflation and interest rates, resulting in a major economic recession that reached its nadir in 1982. Steel demand dropped dramatically as the recession hit the major steel-consuming industries such as construction and car manufacturing. The downturn for the steel industries in industrialized countries was traumatic. Their difficulties were compounded by increasing international competition from low-cost producers among the newly industrialized countries, particularly South Korea and Brazil, and by increasing use of substitute materials in place of steel in key industries.

From 1979 to 1982, steel production in the G-7 countries (the United States, West Germany, the United Kingdom, France, Italy, Japan, and Canada) fell by 21 per cent. Every G-7 country experienced a decline, but the drop was most severe in the United States and the United Kingdom, where steel production was cut almost in half. Even in 1988, after several years of sustained overall economic growth, total G-7 production was still substantially lower than it had been in 1979 and no G-7 country had returned to its 1979 production level.

The downturn of the 1980s precipitated the closing of many uneconomic plants in the industrialized countries and a dramatic reduction in employment in the steel industry. From 1980 to 1990, gross steel capacity in Japan, the United States, the European Economic Community, and Canada declined in total by 21 per cent — from 522 million tonnes to an estimated 410 million tonnes, as shown in Table 2.[1]

The downturn also triggered a surge of technological upgrading to improve product quality, increase labour efficiency, and decrease production costs.[2] Technology improvements were made both by the larger companies operating the integrated mills (which convert virgin iron ore into all kinds of finished steel products) and by smaller firms operating "mini-mills" (which perform a narrower range of processes using mostly scrap steel and produce a more limited range of steel products).

Table 1. Production in major steel-producing countries (1979, 1982, 1988) (thousands of tonnes)

Country and rank in 1988	1979	1982	1988
1. Former Soviet Union*	149 087	147 153	163 046
2. Japan†	111 748	99 548	105 681
3. United States†	123 688	67 656	90 650
4. China	34 484	37 160	59 200
5. West Germany†	46 040	35 880	41 023
6. Brazil	13 893	12 995	24 657
7. Italy†	24 250	24 009	23 699
8. South Korea	7 610	11 758	19 118
9. France†	23 360	18 402	19 106
10. United Kingdom†	21 464	13 704	18 950
11. Poland*	19 218	14 794	16 873
12. Czechoslovakia*	14 817	14 992	15 380
13. Canada†	**16 054**	**11 871**	**15 194**
Total G-7 production	366 604	271 070	314 273
Total world production‡	746 582	644 846	779 649

Source: "Annual review of production and prices," *Iron Age*, (January 1990): 45.

* Production figures for the Communist countries are of uncertain validity
† Member of OECD Group of Seven (G-7)
‡ Includes production from other countries not on list

Table 2. Steel production capacity in industrialized countries (1980, 1990) (million tonnes)

	1980	1990 (est.)	Decline (%)
Japan	159	150	6
EEC	205	142	31
United States	139	100	28
Canada	**19**	**18**	**5**
Total	522	410	21

Source: Britt Doherty, "Canadian steel industry review," *Dominion Securities* (26 January 1987): 2.

Perhaps the most measurable technological advance was the increased use of continuous casting in the integrated mills. The principal benefits of continuous casting are higher yield from liquid steel, higher and more consistent quality, and lower conversion cost. The process does, however, require substantial capital investment.

Canada's Major Competitors

While adjustment to the downturn of the early 1980s was broadly similar throughout the industrialized world, industries in the steel-producing countries adopted different strategies, which have shaped the differing competitive strengths and weaknesses they now exhibit.

United States

The U.S. steel market has a much more direct impact on the Canadian steel industry than does the international market as a whole. The United States is Canada's major export market, taking, in exceptional circumstances, as much as 30 per cent of industry shipments.[3] In addition, U.S. steel prices have a major influence on Canadian prices because of the large indirect trade in steel between the two countries, particularly in cars and auto parts.

The United States entered the 1980s as the largest steel producer among the industrialized countries, with an output of 123 million tonnes in 1979. But its steel industry was also one of the most uncompetitive, because of both outdated machinery and the relatively high value of the U.S. dollar in the early 1980s. The U.S. industry was overtaken in output by the Japanese in 1981. As a result, U.S. firms were forced to undergo a radical restructuring. Over the 1980s, U.S. steelmakers cut capacity by about 30 per cent,[4] cut employment by nearly two-thirds, and mothballed more than 400 plants and steelmaking facilities. The industry invested $18 billion in modernization, but it still lost $12 billion between 1982 and 1986. It would have fared even worse if the Reagan administration had not instituted import quotas.[5]

By the late 1980s, as a result of this massive restructuring and the falling value of the dollar, U.S. companies had closed the gap with many foreign rivals. From mid-1985 to mid-1989, the average cost of U.S. steel fell to $490 a ton from $550, while Japanese steel rose to $520 a ton from $407. U.S. companies also gained on many European rivals, although some, notably British Steel Corp., also drastically improved operations.[6] U.S. labour efficiency rose rapidly, almost on par with that in Japan. U.S. Steel, for instance, reportedly needed 11 person-hours of labour to make a ton of steel in the early 1980s and about 4 person-hours by 1990. One new mill in Indiana, a closely watched experiment by Nucor Corporation, made hot-band steel in 1990 at less than 1 person-hour per ton.[7]

European Economic Community

The European Economic Community underwent a similar but somewhat less dramatic rationalization during the 1980s. Programs coordinated by the integrated steel producers within the EEC were aimed at reducing obsolete capacity, modernizing remaining facilities, restricting expansion, and setting production quotas to establish price stability. In EEC countries with government-owned steel companies, debts for these programs were absorbed by their governments directly. State aid for modernization was also provided to some of the privately owned firms.[8]

Japan

Japan is the largest steel producer among the industrialized countries and is the global leader in terms of long-term growth, profitability, exports, and technological sophistication. Since the 1960s Japan has

set the pace in the international steel industry and has become the competitive standard against which other countries' steel industries are measured.

The development of the steel industry was encouraged by the Japanese government to provide an engine to pull the rest of the economy into the 20th century. The industry recovered amazingly quickly after the devastation of the Second World War, and it began to grow explosively in the 1950s. Production increased at an average rate of 20 per cent per year, and exports at 28 per cent per year through the decade, benefiting from low labour rates and the rapid growth of the economy as a whole. As wage rates climbed, Japanese steelmakers began substituting capital for labour. From 1951 to 1971, Japanese companies built 12 steelworks that were integrated from blast furnaces through finishing mills. Each was the largest — or very nearly — of its kind at the time of construction.[9]

Huge-scale economies and efficient production allowed Japan to keep steel costs down in the 1960s despite rising wage rates. Production climbed from about 40 million tons in 1965 to a peak of almost 120 million tons in 1973. The oil shock and the global economic downturn stopped this growth in its tracks. Since 1973 Japanese steel production has hovered around 100 million tons annually.[10]

Japan's steel industry must import all its iron ore and 89 per cent of its coal. On average, raw materials account for about 52 per cent of manufacturing costs. The industry's heavy dependence on imports makes the competitiveness of Japanese steel companies highly vulnerable to commodity price swings and shifts in exchange rates.[11] Despite this handicap, Japanese companies occupy a predominant position in the world steel industry.

The structure of the Japanese steel industry is characterized by a highly concentrated, integrated producer sector with many mini-mills using electric furnaces. The top five blast-furnace steel manufacturers are extremely large scale. Nippon Steel is the world's largest steel company, and the five integrated companies that dominate the Japanese steel industry are among the top fifteen companies in the world, as indicated in Table 3.

Despite its leadership in the steel industry, Japan, like other industrialized countries, experienced stagnating domestic demand and declining export opportunities during the 1980s. Four factors had a particular impact on the Japanese steel industry: the rise in the value of the yen; the emergence of world-class steelmakers in South Korea and Taiwan; the imposition of import restrictions in the U.S. market; and the decline in oil revenues in the Middle East, which suppressed demand for steel in that region.[12]

In response to the downturn in the market, major Japanese steel manufacturers implemented strict rationalization in the mid-1980s. They closed old and inefficient facilities, upgraded production technology at the remaining plants, and reduced their workforce. Nippon Steel closed three blast furnaces. The top five manufacturers decreased personnel by more than 22 per cent from 1984 to 1988.

This rationalization led not just to a return to profitability in the industry, but to profits that surpassed historic levels. The top five manufacturers went from aggregate net losses of 58 567 million yen in 1986 to aggregate net profits of 231 574 million yen in 1989. Aggregate return on sales went from a 1.0 per cent loss to a 3.2 per cent profit.[13]

In the late 1980s, domestic Japanese steel demand recovered and expanded steadily, in line with the overall economy. Total domestic crude-steel demand in 1988 was about 86 million tons.[14] However, Japan's exports of crude steel dropped substantially from about 35 million tons in 1983 to 18.7 million tons in 1989. During the same period, imports rose slightly to 7 million tons. Two major reasons for reduced exports and increased imports are appreciation of the yen and the expansion of overseas operations of Japanese steel companies, which now import steel into Japan.

Japanese steel companies are taking a number of steps to ensure their profitability and growth in the face of the long-term downward trend in the industry. Some Japanese mini-mills are installing direct-current equipment, which is thought to be substantially more efficient than the alternating-

current systems used in North America. Japan's technologically advanced industries demand high-quality steel, and the steel companies are concentrating on high-value-added products, such as surface-treated steel. They are also diversifying into new businesses — more than 50 per cent of the R&D investments of large Japanese steelmakers are now estimated to be in non-steel R&D.[15]

Table 3. World's leading steel companies (1989)

Company	Country	Crude-steel production (million tons)	Sales (U.S.$ million)	Sales (U.S.$/ton)
1. Nippon Steel Corp.	Japan	28.4	19 956.3	703
2. Group Usinor Sacilor	France	23.0	16 240.5	706
3. Pohang Iron and Steel Corp.	South Korea	15.5	6 421.9	414
4. British Steel PLC	United Kingdom	14.2	8 285.2	583
5. USX Corp.*	United Kingdom	12.9	18 717.0	1 451
6. NKK Corp.	Japan	12.3	10 447.7	849
7. Thyssen AG*	West Germany	11.6	18 430.5	1 589
8. ILVA S.p.A.	Italy	11.4	8 500.6	746
9. Bethlehem Steel Corp	United States	11.1	5 250.9	473
10. Kawasaki Steel	Japan	11.0	8 641.1	786
11. Sumitomo Metals	Japan	11.0	9 264.5	842
12. Steel Authority of India	India	8.5	—	—
13. LTV Corp.	United States	7.7	6 362.0	826
14. ISCOR Ltd.	South Africa	7.0	2 142.2	306
15. Kobe Steel	Japan	6.5	9 454.9	1 455

Source: Corporate Directions Inc., "The Japanese steel industry: industry structure and technology strategies," contract report prepared for the Science Council of Canada, 1990 (unpublished), 4.

* USX and Thyssen both derive considerable income from non-steel activities (diversification).

Japanese steel manufacturers have responded to U.S. steel quotas by investing in U.S. companies. They now hold a substantial interest in major U.S. steelmaking operations. For example, Kawasaki Steel of Japan acquired a 40 per cent share of Armco Steel Co. in 1989, and NKK increased its share of National Steel Corp. to 70 per cent in 1990. Several Japanese steel companies have also entered into joint ventures or strategic partnerships with U.S. counterparts.[16]

The Japanese firms have followed a strategy of trading their advanced technology and low-cost capital for what are, in effect, equity positions in U.S. companies. With a declining market for steel in

North America, it is difficult for any company to justify building new integrated iron and steel facilities. Transportation costs and potentially uncomfortable Congressional hearings militate against direct exports of steel from Japan to the United States. Therefore, Japanese investment in the U.S. steel industry has been concentrated on upgrading existing facilities.

These investments in upgrading have been helped by the presence of the new Japanese 'transplant' auto-production facilities in the United States. The transplants insist on the same quality steel for their cars as used in Japan, and U.S. firms cannot supply the required quality unless their plants are upgraded. The Japanese automobile companies are therefore using their presence in the automotive marketplace to enhance the quality levels of suppliers to the industry.

The Japanese car industry has played a critical role in the development of Japan's steel industry by becoming its most demanding customer. In the early 1970s, Japanese car exports to North America had a poor reputation because of low rust resistance. The manufacturers therefore put pressure on Japanese steel producers to upgrade the quality of the steel they supplied to the auto industry. The magnitude of their steel purchases gave them the market strength to force steel manufacturers to produce the quality of steel they needed.

Many steel firms also have some financial relationship to downstream users of their products, such as the auto companies.

Rationalization of the Japanese steel industry is continuing. Further plant closings and personnel reductions are planned for the early 1990s. Three of Japan's major steel companies — Nippon Steel, NKK, and Sumitomo — reported plans to reduce their workforce by 6 per cent, or 6 100 jobs, from March 1990 to March 1991.[17] Companies are also increasing their capital investment and shifting to more efficient, less labour-intensive machinery, with the goal of maintaining their dominant position in world markets.

Competitive Pressures in the Global Steel Industry

The major restructuring and rationalization occurring in the steel industry in industrialized countries are being offset to a considerable extent by increased steel production and capacity growth in newly industrialized countries with lower labour costs.

Brazil and South Korea joined the ranks of the top 10 steel-producing nations in the 1980s. From 1979 to 1988, production increased from 13 893 thousand tonnes to 24 657 thousand tonnes in Brazil and from 7 610 thousand tonnes to 19 118 thousand tonnes in South Korea.[18] Total capacity in all the developing countries increased from 86 million tonnes in 1980 to about 145 million tonnes by 1990.[19]

In Brazil, one reason for the expansion was to increase exports to about 50 per cent of production. But restructuring is now taking place to reduce production. This should stabilize the domestic market in light of declining growth in Brazilian demand caused by the current economic climate. There are plans to privatize the industry to attract foreign investment, but uncertainties about the country's economy have not only delayed privatization plans but also put major new investment projects on hold throughout the steel industry. Despite these current difficulties, Brazil's future as a major player in the steel industry is promising, as it is the largest iron-ore producer in the Western world.

In addition to declining competitiveness relative to steel producers in developing countries, steelmakers in the industrialized countries are threatened by reduced domestic demand. In most advanced economies, steel for construction is largely a replacement market, while other major users are consuming less steel as they shift to substitute materials.

In the auto industry, for example, steel consumption has declined dramatically. From 1975 through 1983, in the aftermath of the first oil shock, auto manufacturers concentrated on increasing fuel efficiency, largely by reducing the size and weight of cars. The average weight of Ford's U.S. passenger cars fell by 1200 pounds, reaching 2607 pounds at the end of the period. The bulk of this loss was at the expense of carbon steel and cast iron.[20]

As well as downsizing, manufacturers shifted to substitute materials and higher quality steels that reduce the total quantity of steel needed. From the 1950s through the 1980s, the materials in a typical passenger car underwent a striking change. Mild sheet steel generally made up 65 per cent or more of the weight of the average Ford in the 1950s, but only 50 per cent by 1985. In its place, manufacturers used cast aluminum, plastics, and high-strength steel. Overall, the content of lightweight materials in the average Ford rose from 9 per cent in 1975 to more than 23 per cent 10 years later.[21]

The trend to substitute materials shows no signs of abating and could further threaten the steel industry. The move to one- and two-sided galvanized auto sheet steel has also narrowed the price gap for substitutes and raised manufacturing (e.g., welding) costs. Lightweight, high-strength, low-alloy steels will continue to replace carbon steels. A worst-case scenario for the steel industry would see cars 15 or 20 years from now made mostly of lightweight substitute materials, such as aluminum and plastics, with very little steel content.[22]

Indeed, this steel-industry nightmare may already be starting. The body of the new Japanese NSX sports car, made by Acura, is a novel composite material based on aluminum and plastics. Jaguar's proposed XJ220 will use Alcan's aluminum structural vehicle technology if this vehicle goes into production. This technology allows the production of aluminum auto bodies on conventional production lines and could lead to the development of passenger cars made primarily from aluminum.[23] Japanese steel companies are conducting research into adapting conventional steel-stamping processes for aluminum sheet.

Further declines in world steel markets and in steel production in the industrialized countries can be expected over the decade. The major challenge facing steelmakers in these countries, including Canada, is to devise strategies to cope with shrinking domestic markets and increasing competition. Possible strategies include continued downsizing and rationalization to bring supply in line with demand and make operations more efficient, moving into specialized high-value-added steel products, and diversifying into new non-steel businesses with higher growth prospects.

R&D in the Global Steel Sector

Considerable variation exists in the level of intensity of R&D investment, as shown in Table 4. There are, however, many caveats to interpretation of these data. R&D as a percentage of sales provides little indication of the level and type of R&D effort or the critical mass of R&D required to achieve technology leadership. Nor does it measure the success of R&D performance, whether in patents, publications, or products.

Table 4. Steel-industry R&D expenditures in selected countries (1987)

	% of sales
Japan	1.50
South Korea	0.87
Taiwan	0.87
Austria	0.82
Australia	0.67
West Germany	0.61
Netherlands	0.60
United Kingdom	0.57
United States	0.51
South Africa	0.42
Brazil	0.39
Canada	**0.25**

Source: International Iron and Steel Institute. Cited in Jonathan P. Hicks, "Rusty research imperils U.S. steel firms," *International Herald Tribune* (15 August 1989).

In comparing national R&D levels, one must be aware that definitions of R&D vary from country to country.[24] But even when different national definitions are taken into account, Japanese industrial R&D in iron and steel is more than twice the level it is in North America.[25]

R&D by Canada's Major Competitors

Canada's major competitors in steel — the United States, Japan, and Europe — differ widely in their R&D strengths and strategies. These differences are important and should be kept in mind when technology strategies and policies for the Canadian steel industry are developed.

United States

U.S. companies spend relatively little on R&D and have been slow to adopt new technologies such as continuous casting. Annual R&D spending by the entire U.S. steel industry is less than the

$200 million spent annually by just one Japanese company, Nippon Steel. Innovation in the U.S. steel industry is confined primarily to finishing processes such as continuous galvanizing. Companies were not pushed into innovation by major customers demanding better products, as in Japan. For many decades U.S. steelmakers were able to maintain competitiveness despite little R&D expenditure, achieving scale economies and satisfying mass markets through the use of mainly foreign-developed technologies.

Although steel-industry rationalization and depreciation of the U.S. dollar during the 1980s allowed the industry to regain international competitiveness, overall neglect of R&D by steelmakers in the United States may mean that they are winning the battle but losing the war.

According to Jonathan M. Aylen, a steel-industry analyst from Britain's University of Salford, "The American steel industry is so far behind in R&D that it's doubtful it can ever catch up. As a result, the typical American steel plant is likely to become an industrial museum."[26] And according to the chairman of the U.S. steel firm Inland, its partner Nippon Steel has "the technological capability of the whole U.S. steel industry put together."[27]

European Economic Community

Many of the iron and steelmaking technologies in current use worldwide originated or were significantly developed in Europe. Except for the electric-arc furnace, which dates back to the early years of this century, most technologies were developed or commercialized in the last 50 years. Significant examples include the L-D furnace, named after the towns of Linz and Donawitz in Austria, where it was developed (known as the basic oxygen furnace in North America); continuous casting, developed in Germany; and direct reduction of iron, developed in Sweden.

During the 1980s, while Japan's steel industry diversified its R&D efforts and U.S. firms reduced their research somewhat, companies in western Europe generally maintained steady levels of spending and employment on traditional areas of iron and steel research. Although the stock of knowledge that Japanese steel companies accumulated during 20 years of independent technical development still makes them leaders in steel technology, world leadership may shift to Europe in the future. The prospect of world R&D leadership for Europe exists not only in new fields such as plasma smelting and in areas of traditional European strength exemplified by electric-arc furnaces, but also in some ironmaking technologies recently dominated by the Japanese.

Japan

The Japanese steel industry, with virtually no raw materials and with high energy costs, has captured international leadership by continuous improvements to process and product technology. Japan's technological edge can be traced to rapid adoption of foreign technology and very high Japanese R&D expenditures over the past 20 to 30 years. Japan is the world leader in steel-industry R&D.

The extremely high level of steel industry R&D expenditures in Japan reflects in part the strategic diversification by Japanese steel producers during the 1980s. R&D expenditures specifically on iron and steel represented about 1 per cent of industry revenues at the start of the 1980s and probably remained at about that level throughout the decade. The increase in industry R&D to 1.5 per cent of sales is the result of diversification of steel companies into new materials and processes such as titanium, fine ceramics, superalloys, and powder metallurgy, and into non-materials businesses such as electronics, biotechnology, information, and communications.[28]

It is noteworthy that Japanese R&D investments have paid off handsomely, despite the traditional conventional wisdom among steelmakers that the basic processes were well understood globally and that accordingly there was little prospect of any significant competitive gains from large additional R&D expenditures. The Japanese steel industry sees steel as continuing to play an important but different role by the year 2000. There will be new types of steel for new markets such as the high-

tech industries, and in some traditional markets steel will be replaced by new materials. The industry is therefore not only seeking to prolong the lifetime of the current industry by looking at new types of steel and new uses for steel, but also preparing to participate in producing the new materials that will replace steel in the future.

Industry R&D expenditures increased until the early 1980s to the point where Japanese companies accounted for about 50 per cent of total R&D spending worldwide in iron and steel. It is now clear, however, that Japanese ferrous-metals R&D is declining as leading Japanese steel firms attempt to diversify their R&D effort to offset declining competitiveness of steel products.[29] Despite this, Japan's iron and steel R&D investment, in terms of both spending and personnel, is larger than that of any other member country in the Organization for Economic Co-operation and Development.

In contrast to the United States, Japan has been quick to adopt new technologies and has spared no effort to develop them almost to perfection.[30] Most Japanese companies operate applied-research laboratories and extensive pilot-plant facilities. Many companies, unlike any U.S. or Canadian firms, also have basic-research groups or laboratories.

The strong demand from sophisticated end-users in Japan led to a growing focus on downstream R&D and new-product development in the 1980s. In addition, there has also been a shift toward greater emphasis on breakthrough research. Once upon a time, Japanese steel companies adopted technology from abroad. Now they focus on developing their own technology, and they have started to export technology.

The Japanese government supports steel-industry R&D consortia involved in long-term, high-risk projects. For example, Japan's Ministry of International Trade and Industry (MITI) orchestrated a national R&D program to develop the near-net-shape casting of steel. The program maximized the scope of the effort and minimized duplication by allocating to each of the major steel companies R&D into a different process and product-thickness range.[31] Another MITI-directed project, involving five steel companies with NKK as the leader, is developing a new thin-slab casting technology that allows continuous casting to be tied together with the finishing portion of hot-strip rolling. Molten steel can be converted into sheet bars with all intervening steps skipped.

Process research

Japanese process research is driven by the specific requirements of Japan's steel industry. The industry must contend with high energy costs, rising labour costs, an appreciating yen, and demands for high-quality materials from Japan's advanced end-user industries. Therefore, Japanese research in process technology focuses on enhanced productivity; energy, labour, and other costs; and quality.

Intensive efforts to improve production processes have given Japan the highest furnace productivity in the world. Productivity has been enhanced by rationalization and by a focus on continuous-process technology to increase yields and cut costs. Approximately 93.5 per cent of Japan's crude steel is now produced by continuous casters.[32]

Intensive R&D has also made Japan's steel producers the most energy efficient in the world. In 1989, they required 1.00 kilowatt hour (kWh) of electricity to produce 1 ton of steel, well below the world average of 1.28 kWh and the North American average of 1.37 kWh. Technological advances such as the "oil-less" blast furnace have focused on reduced oil consumption and the recovery and recycling of discharge gases. Between 1973 and 1984, oil consumption by Japanese steelmakers fell by 77 per cent.[33]

End-users' demands for high-quality steel have led to the development of process technologies that increase the performance of steel. For example, Kawasaki Steel developed extra-high tensile-strength maraging steel with exceptional fracture toughness. This innovation involves a special treatment that reduces impurities during the production process.

Product research

Product-technology R&D in Japan is driven mainly by demand from sophisticated end-users and by a policy of strategic diversification by the steel companies.

Demand for value-added coated-steel products from automobile and electric appliance companies has led to the development of advanced coating technologies. For example, nickel-zinc alloy electrogalvanized steel sheets are rust resistant and are in demand by Japanese automakers, while precoated steel sheets have high-brilliance, workability, and adhesive properties, and are popular with appliance makers.

Steel companies are also satisfying the growing demand for value-added products in the construction industry. Sumitomo Metals developed a new type of steel pile for waterfront development that is coated with a corrosion-resistant urethane elastomer that can be produced in a variety of colours to match its surroundings.

In addition to developing high-value-added steel products, companies are diversifying into new businesses and investing increasing amounts in non-steel research. NKK makes 80 per cent of its profits from steel but dedicates 67 per cent of its research to new non-steel products and new business development.[34]

Nippon Steel Corporation plans to reduce steel production to 50 per cent or less of its total business by 1995, but it intends to increase the cost competitiveness and profits of its steel business and use steel as a cash cow to finance the company's diversification scheme.[35] Its business interests will extend to other materials, including chemicals, electronics, information/communications systems, and biotechnology. Should steel demand increase, the company is flexible enough to adapt its strategy to cater to that demand.

Kawasaki Steel Corporation, like Nippon, is using the steel side of its business to finance development into other areas, including ceramics, resins and composite materials, electronics, and advanced materials. Kawasaki Steel aims to reduce steel to 60 per cent of total sales by the year 2000.

Kobe Steel plans to be a "comprehensive materials producer" by the year 2000. Plastic processing, powder metallurgy, and advanced materials will add to the company's already strong base in steel and aluminum. The company also plans to branch further into electronics and biotechnology. Kobe's R&D is not confined to Japan. A company laboratory at the University of Surrey in England is investigating polymer composites, and another at the Research Triangle Park in North Carolina is conducting research on thin-film materials for electronic applications. Kobe is building an international system of research centres linked by a computer network to coordinate their activities.

Although Japan lacks such key competitive advantages as natural resources and cheap labour and energy, its steel companies have achieved high levels of quality, productivity, and energy efficiency through R&D. Japanese steel manufacturers change their R&D focus according to changing market needs. From the 1950s to the 1970s, they met market demand for low-cost steel and adapted process technologies developed elsewhere. In the 1990s, they are shifting to high-value-added steel products and to product and process breakthroughs, as well as diversifying into new non-steel businesses. As a result, Japanese steel companies will remain highly competitive in the value-added sections of the steel industry while ensuring their future through increasing participation in other industries with higher long-term growth potential.

How Canada Compares with Competitors

Several factors help to explain Canada's exceptionally low R&D spending. One is the attitude and short-term outlook of leading Canadian companies. In Canada, as in the United States, R&D has been regarded as an expense; in countries like Japan it is seen as an investment. The distinction is

important. In Canada, R&D is viewed as expendable when company fortunes decline rather than as an investment in the company's future.

A second factor is that Canadian end-use customers have exerted less pressure for more advanced steel products than their counterparts in Japan and Europe.

A third factor is that, until recently, the relatively sheltered Canadian environment lacked significant competitive pressures to improve cost structures, process technologies, or product offerings. Steel companies could remain profitable without doing much R&D.

A fourth factor is the cost of research. *Steel Times International*[36] suggests that one reason for low R&D in North America is the higher cost of doing research. In Europe the costs of researchers are lower, and in Japan the cost of capital is also significantly lower.

A fifth factor is that the industry has not succeeded in persuading the federal government to support its proposal for research assistance through the Centres of Excellence program.

Whatever the reasons, R&D in the steel industry is lower in Canada than in other traditional steel-producing countries or in the leading developing countries.

The Canadian Steel Sector

Canada is a relatively small player in the world steel industry. It is the world's 13th largest steel-producing nation but produces less than 2 per cent of the world's crude steel. No Canadian company ranks among the world's top 15 companies. Table 5 shows Canada's steel production relative to that of other major steel producers.

Table 5. Distribution of world steel production (1988)

	% of world production
EEC (11 countries)	17.54
Japan	13.57
United States	11.52
Canada	**1.92**
Other	55.45
World total	100.00

Source: Hatch Associates, "R&D in the Canadian iron and steel sector," contract report prepared for the Science Council of Canada, 1990, (unpublished), 8.

The Canadian steel industry produces a full range of steel products. The industry consists of 11 companies, which operate 18 plants in Canada, half of them in Ontario. The markets for steel from integrated mills include high-quality steel for automobiles, appliances, and consumer products. Mini-mills supply steel for a narrower range of markets such as the construction industry and pipelines, but with new technology the mini-mills are challenging the large integrated mills.

There are two major integrated producers, Dofasco/Algoma and Stelco. Their plants are concentrated in Ontario and serve national markets. The remaining firms operate mini-mills that supply regional markets across the country.

Dofasco/Algoma and Stelco together account for about three-quarters of the country's steelmaking capacity, as indicated in Table 6. They use blast-furnace (BF) ironmaking and basic oxygen furnace (BOF) steelmaking to make steel from iron ore. Dofasco, since its purchase of Algoma Steel for $562 million in 1988, surpasses Stelco as the largest steel company in Canada. In early 1991, Dofasco and Stelco were both forced to cut dividends because of serious financial problems. Stelco's losses for 1990 amounted to $196.7 million. Dofasco had to completely write off its investment to purchase Algoma Steel Corp. of Sault Ste. Marie, Ontario. This turned a potential profit of over $100 million for 1990 into a loss of $679 million. Dofasco's main interest in Algoma was in its capacity to supply slab steel for Dofasco's Hamilton cold-mill complex, which is expected to come on stream in 1992 and will provide steel mainly for the auto industry.

Canadian producers have access to abundant raw material (iron ore, coking coal, limestone, scrap) at reasonable cost and within relatively short shipping distances. The low price of electricity relative to that in most other countries[37] is important because electricity is the primary cost input required to run a mini-mill.

Table 6. Canadian crude-steel capacity (1988)

Company	Capacity (million tonnes)	% of total
Dofasco/Algoma	7.55	44
Stelco	4.71	27
Sidbec Dosco	1.50	9
Lasco	0.90	5
Ipsco	0.73	4
Atlas	0.37	2
Ivaco	0.36	2
Slater	0.30	2
Manitoba	0.27	2
Courtice	0.25	1
Sydney Steel	0.20	1
Total	17.14	99

Source: Canada Consulting Cresap, "Sector overview: primary iron and steel," contract report prepared for the Science Council of Canada, 1990 (unpublished).

Proximity to major markets in central Canada and the United States is another important advantage. Transportation costs tend to shield these major markets for Canadian steel from low-cost offshore competitors, although they also constrain the major steel producers in central Canada from exporting to offshore destinations. Transportation costs also benefit mini-mills, which capitalize on scrap steel that is available in all major urban areas. There are mini-mills in Ontario, Manitoba, Saskatchewan, Alberta, Quebec, and Atlantic Canada.

In 1988, the Canadian steel industry had total sales of nearly C$9 billion and employed some 43 000 people. It produced approximately 15 million tonnes of 'raw' steel, which is steel in its first solid form before it is rolled to finished product.[38]

In the early 1980s, demand for steel eroded less in Canada than in the United States, and Canadian capacity did not change substantially during the decade. However, the Canadian industry modernized at unprecedented levels. From 1979 to 1988, capital expenditures averaged $500 million annually, or about 7 per cent of sales. In the United States, the comparable figures are $1800 million per year and 5.8 per cent of sales.[39]

Much of the Canadian investment was made by the large integrated steelmakers to install continuous-casting equipment, which lowers manufacturing costs by about 10 per cent and increases steel quality. Many automakers now insist on the superior steel made by this process.[40]

Canadian electric-arc furnace (EAF) mini-mills have also adopted new technologies and have steadily increased their percentage of the North American market. The mini-mills are currently attempting to enter the flat-products sector, which is dominated by the large integrated companies and represents about half of the total rolled-steel market. The expertise required to master the market,

product, and technology differ significantly from traditional mini-mill expertise, and successful penetration is not assured.[41]

The traditional business strategy of Canadian steel firms was to build capacity to meet only 'base-load' or continuous demand. This kept costs low but meant that imports were needed whenever the economy rose to a cyclical peak.

If Canadian firms had built greater capacity, they would have had to export excess production during periods of cyclical downturn. Despite the advantages of high-quality iron ore reserves and low energy costs, Canadian firms would have had difficulty competing in U.S. and overseas export markets. They would have faced higher transportation costs when selling overseas. More important, in any given business cycle, U.S. producers would also have had excess production capacity, and could have used marginal cost pricing (i.e., cut prices temporarily to cover only operating expenses). Although marginal cost pricing is only an interim solution, it would have been enough to keep U.S. steel prices competitive with exported Canadian steels. In addition, Canadian steelmakers would have to maintain competitive prices despite currency fluctuations. The relatively high value of the Canadian dollar is a limiting factor at present.

The level of real access to the U.S. market is a controversial and sensitive issue. Does the Free Trade Agreement between Canada and the United States have positive implications for Canadian steel firms? Will it enable them to turn outward, to become more export oriented and competitive in world markets, or will they remain tied and doomed to continue serving the small internal market? Some Canadian steel-industry executives suggest there is now little real opportunity for Canadian steel firms to further expand exports into the U.S. market, in part because of fears that U.S. steel producers may take further actions and that the lack of agreement on trade rules could still trigger U.S. accusations of dumping by the Canadian industry.

R&D

Canadian steel-industry expenditures on R&D as a percentage of sales have remained in the 0.3 to 0.4 per cent range since 1975, according to Statistics Canada.[42] This is relatively low by international standards, as estimated by the International Iron and Steel Institute (see Table 4). Both as a percentage of sales and in absolute terms, the Canadian steel-industry's R&D expenditures are the smallest among the G-7 countries.[43]

Table 7 summarizes Canadian private- and public-sector iron and steel R&D expenditures and personnel. Expenditures on R&D performed by the Canadian iron and steel industry averaged about $31 million per year from 1987 through 1989. Iron and steel research conducted in government laboratories amounted to about $5.1 million annually over the same period, while university research was estimated to be $10 million annually.[44] Thus, total Canadian expenditures on iron and steel R&D are approximately $46.1 million annually.[45]

Facilities devoted to iron and steel R&D in Canada consist of two large integrated laboratories run by Stelco and Dofasco and a few laboratories run by mini-mills. There are also four federal government laboratories that cover other technologies as well as iron and steel. In addition, six Canadian universities conduct substantial research relating to iron and steel. The Canadian Steel Industry Research Association (CSIRA) provides a communications network but does not do research itself.

The principal industry laboratories are operated by Stelco in Burlington, Ontario and Dofasco in Hamilton, Ontario. Algoma, now part of Dofasco, has a small R&D group in Sault Ste. Marie, Ontario. Mini-mill R&D facilities are small, but Canadian electric-arc furnaces represent leading-edge technology, and Co-Steel, which owns Lake Ontario Steel (Lasco) in Whitby, is recognized as a world

Table 7. Canadian iron and steel R&D expenditures and personnel (1988)

	Million $	Personnel
Industry	31.0	
Integrated producers		220
Mini-mills		20
CANMET*		
Metals Technology Laboratories	2.9	22
Mineral Sciences Laboratories	0.7	4
Energy Research Laboratories	0.5	8
National Research Council of Canada		
Industrial Materials Research Institute	1.0	10
Universities	10.0	
Professors		14
Graduate students		18
Total	46.1	316

Source: Hatch Associates, "R&D in the Canadian iron and steel sector," contract report prepared for the Science Council of Canada, 1990 (unpublished), 10-20.

* Canada Centre for Mineral and Energy Technology (Energy, Mines and Resources Canada)

leader in EAF steel-production technology. Lasco led the mini-mill revolution of the 1960s and 1970s and is the lowest cost producer in its market.

On average, 245 people were employed in steel-industry R&D in the 1980s. The number is slowly declining. At Stelco the average was 115; at Dofasco, 71.[46]

Government iron and steel R&D is conducted primarily by the Canada Centre for Mineral and Energy Technology (CANMET). CANMET is the main research and technology-development arm of Energy, Mines and Resources Canada. In partnership with its clients, CANMET performs and sponsors predominantly commercial and cost-shared R&D and technology transfer to improve the competitiveness of the Canadian minerals, metals, and energy industries.

Three of CANMET's laboratories are involved in iron and steel R&D. The bulk of this is performed in CANMET's Metals Technology Laboratories in Ottawa, which is the largest research centre in Canada dedicated to metals processing and evaluation. About half of its 110 employees are involved in steel-related research, and 22 employees (20 per cent) are engaged in activities directly related to primary production. CANMET's Mineral Sciences Laboratories dedicate four person-years and CANMET's Energy Research Laboratories dedicate eight person-years annually to R&D relating to iron and steel. The National Research Council's Industrial Materials Research Institute has 10 people involved in iron and steel R&D.[47]

Six universities dominate iron and steel research: The University of British Columbia (Stelco-NSERC Chair), École polytechnique, McGill University (CSIRA-NSERC Chair), McMaster University (Stelco Chair), University of Toronto, and University of Waterloo. From 1983 to 1988, about 150 graduate degrees were conferred by the metallurgical departments of these universities, and at least 60 per cent of these students had been engaged in iron and steel research.[48]

CSIRA was formed in 1978 to foster cooperation among universities, industry, and government, and to ensure that research and development efforts benefit the Canadian industry. The association performs a networking and communications function but does not conduct R&D itself. Networking is vital in this sector because so much important research is performed by government laboratories and universities. Funding for CSIRA comes from a levy on each member company; as well, the federal government contributes to specific activities.[49]

One notable achievement of CSIRA is its initiation of "Projet Bessemer," a recently formed Canadian consortium dedicated to developing a near-net-shape casting process to produce thin strip directly from liquid steel. The thin-strip process has been under investigation worldwide for some years. It is used in some small-scale production of high-value materials such as stainless steel and amorphous metals. In 1990 the process was finally proved suitable for large-scale production of carbon steels by Nucor Corporation, the 10th largest U.S. steel company. Nucor operates the world's first continuous-steelmaking machine for making sheet metal, a compact-strip-production facility in Indiana based on a German invention, and the firm is building a second thin-slab mill in Arkansas. The new process that Projet Bessemer is concerned with would eliminate several steps from the conventional process of casting the liquid steel into slabs and then rolling the slabs into finished strip. This would lower costs significantly.

The Projet Bessemer consortium consists of six of the largest Canadian steel companies. The companies are providing $35 million in this five-year project, and the federal government is providing an additional $7.5 million. This is the steel industry's most ambitious cooperative R&D project. However, the project is small by world standards, and the industry's contribution of $7 million annually over the five-year period is trivial relative to the sector's $9 billion in annual sales.[50]

Competitiveness

Until very recently, the Canadian steel industry seemed prosperous and competitive. Canadian steel shipments increased at an average of nearly 7 per cent per year between 1950 and 1970. Then from 1970 to 1988, the average growth rate was about 1.6 per cent, but rates were highly cyclical during this period. This pattern was broadly similar to world steel growth, but Canada did significantly better than other industrialized countries, particularly the United States. Raw-steel production in the United States declined from a peak of 137 million tonnes in 1973 to about 90 million tonnes in 1988.[51]

Growth in the Canadian steel industry from the early 1970s was entirely the result of increased exports. In Canada, as in other industrialized nations, domestic demand has been falling. Between 1973 and 1986, domestic steel shipments decreased on average by 45 000 tonnes per year. But the rise in exports of about 161 000 tonnes annually more than offset the decline in domestic sales.[52]

Exports fell during industry downturns, but the overall increase was from about 1 million tonnes annually in the early 1970s to about 4 million tonnes from 1986 through 1988. A fall in U.S. steel production stemming from a labour dispute was responsible for the 1987 peak in Canadian exports of 4 234 thousand tonnes or 30 per cent of total Canadian industry shipments of 14 053 thousand tonnes. Some 3 670 thousand tonnes, or 87 per cent of these exports, went to the United States.[53]

This success in the U.S. market may give the false impression that the competitiveness of Canadian steel producers was improving. But the United States did not represent the leading-edge market; U.S. firms, like Canadian firms, could not compete against the more advanced technology of the Japanese.

However, the growth in exports was reflected in industry profits. Net income averaged 2.4 per cent of sales from 1982 to 1988. This was only slightly below the Japanese industry's performance. Over the same period, the U.S. industry average was minus 6 per cent.[54]

More recently, Canadian steel exports have been falling and imports rising. From 1987 to 1989, Canadian exports fell from 4.2 per cent to 3.2 per cent of the U.S. market, while U.S. imports rose from 4.7 per cent to 8.4 per cent of Canadian consumption.[55] Although currency swings were the major reason, technology also played a part. Joint ventures with Japanese firms are helping the U.S. industry increase its market share in North America. In 1990, foreign penetration of Canadian steel markets jumped to over 24 per cent, a rise from nearly 19 per cent in 1989. The main increase was in imports from the United States.

Declining cost competitiveness may be an important factor in Canada's worsening balance of trade in steel with the United States. Table 8 indicates that in 1985 Canada was the lowest cost steel producer among industrialized countries. Canada's cost advantage was substantial when transportation costs to the North American market were taken into account. But as Table 9 indicates, by May 1989 this cost advantage had seriously deteriorated, partly because of an appreciating exchange rate relative to the United States.

Table 8. Steel production costs in major steel-producing countries (1985) (hot-rolled steel coils)

	% of U.S. costs	
	FOB steel mill	Delivered to United States or Canada
United States	100	100
Japan	87	110
EEC	87	110
Canada	**86**	**86**
Brazil	59	83
South Korea	56	80

Source: Industry, Science and Technology Canada, *Industry Profile: Primary Iron and Steel* (Ottawa: 1988): 4.

For cold-rolled steel, the product analysed in Table 9, production costs in Canada were second only to those of the United States among major producers in the industrialized world. The high Canadian costs were driven by wage rates higher than all but U.S. rates and by the lowest labour productivity (hours per tonne) among major industrialized producers. Canada's cost advantages relative to the United States were almost entirely because of lower materials and energy costs.

The low level of labour productivity suggests that, in addition to its cost competitiveness, Canada was losing its technological edge in the North American industry.

Despite its low R&D investment, the Canadian steel industry has seen itself as a technological leader in North America. Some Canadian steel companies, although not generally innovators, have been quick to adopt new technologies. Atlas Steels and Premier Steel (now Stelco's Edmonton Works) were the first in North America to adopt continuous casting, and Dofasco was the first to install the BOF steelmaking process.[56] Significant innovations include Stelco's "Coilbox" and "Stelmor" wire rod.

Table 9. Steel production costs in major steel-producing countries (May 1989) (cold-rolled; integrated plant)

	Production costs (U.S.$/tonne)			Labour component	
Country	Materials cost	Labour cost	Total cost	Hours/tonne	U.S.$/hour
United States	303	158	461	6.2	25.5
Canada	**277**	**157**	**434**	**6.7**	**23.5**
Japan	290	135	425	6.6	20.5
Germany	285	118	403	6.4	18.5
France	282	115	397	6.4	18.0
United Kingdom	293	96	389	6.4	15.0
Former Soviet Union	300	58	358	14.5	4.0
Korea	292	56	348	8.4	6.7
Brazil	246	52	298	14.4	3.0

Source: Canada Consulting Cresap, "Sector overview: primary iron and steel," contract report prepared for the Science Council of Canada, 1990 (unpublished).

There are, however, few examples of Canadian leadership in adopting new technology in recent years. Continuous casting is the major technological improvement instituted by integrated steelmakers during the past 15 years. The percentage of steel that is continuously cast is often used as a measure of an industry's utilization of modern technology in primary steelmaking. Japan and the EEC were quicker to adopt continuous casting than Canada and the United States and reaped the quality and cost advantages that are critical to competition in international markets. Dofasco tried a "direct rolling" process that offered very high process efficiency, but it did not offer quality.

In 1978, about 20 percent of Canadian and U.S. raw steel was continuously cast. By 1988, the percentage had risen to 69 per cent in Canada and 61 per cent in the United States. But as Table 10 shows, this was still behind the EEC and Japan.[57] Continuous casting is not, of course, the only indicator of modern process technology or quality of output.

The level of R&D spending has probably been of only secondary importance in influencing the general competitiveness of the Canadian steel industry, at least until recently. A strategy of technology purchase is likely to continue, but this approach still requires some R&D to fully complement purchased technologies and make continual improvements. In interviews conducted for the Science Council, executives in the large integrated companies stated that research is not a critical success factor in the industry. They argued that technology is easily purchased and quickly disseminated and that innovation 'payout' is derived from adopting and adapting the best practices from around the world. Canadian companies cite the Japanese, who for many years had a relatively poor innovation record but were early adopters and used their development strengths to adapt and optimize borrowed or purchased technology.[58] The research director of a medium-sized Canadian steel firm remarked, "The most effective R&D is a set of airline tickets."[59]

Table 10. Continuous-cast steel production in industrialized countries (1988)

	% continuous cast
Japan	93
EEC (11 countries)	84
Canada	**69**
United States	61
Western world average	77
World average	59

Source: Hatch Associates, "R&D in the Canadian iron and steel sector," contract report prepared for the Science Council of Canada, 1990 (unpublished), 8.

As in the past, Canadian steel companies focus most of their R&D today — 85 per cent — on improving existing processes to achieve cost reduction and quality enhancement. Very little effort is dedicated to developing new-product technology.[60]

But in an industry where the pace of technological change in products is accelerating and competition from low-cost producers is increasing, it is doubtful that Canadian steelmakers can survive on a low-R&D, adopt-and-adapt strategy that emphasizes process technology. To remain competitive, the industry must substantially increase its efforts to adapt processes and generate product innovation. A thoroughly competent complement of technologists is generally needed even to adapt a purchased innovation to suit a company's particular needs.

To offset its high labour costs, the Canadian steel industry must seek benefits from process technologies that improve productivity if it is to compete against countries like South Korea and Brazil, which have much lower labour rates. To stay ahead, both steel companies and their customers must be receptive to a strategy that combines development targeted at specific markets with the continued and timely application of leading-edge process technologies. Projet Bessemer is an important though small step in this direction.

The Canadian steel industry will also have to find a way to participate in and reap the benefits from important areas of research such as direct steelmaking, which eliminates the need for coke ovens. The Japanese steel industry has invested $250 million and a consortium of European steel companies has already spent about $100 million in direct-steelmaking research in the last three years. In the United States, the Department of Energy and the leading steel companies plan to spend nearly $30 million on a similar project over the next three years.[61]

Canada does no research in direct steelmaking, and Canadian companies lack the resources to support research on a scale comparable to these European and U.S. projects. One option is to establish joint ventures to enable participation in foreign research projects in this and other areas. Stelco, for example, has established a joint venture in process technology with a Japanese company, Mitsubishi Steel.

To compete against low-cost commodity-steel producers, Canadian companies need also, like the Japanese, to develop more high-value-added steel products and to diversify into related sectors with higher growth potential.

Some executives in the Canadian steel industry are well aware of the need to increase R&D in new-product technologies. In interviews conducted for the Science Council, one stated: "With the

demand for commodity steel levelling off, the importance of R&D will increase. Our company will have to grow via higher value-added products. Longer term, we envision directing a growing proportion of R&D effort into fundamental research." Another observed: "We want to compete on the basis of product differentiation and quality, not price."[62] But the current poor financial situation of the leading Canadian firms seriously constrains their capacity to explore this option.

The slump has hit Stelco particularly hard. Figures for third-quarter earnings released at the end of October 1990 showed that Stelco had lost $55.9 million — a drop of almost $140 million from the same period in 1989, when the company earned $83.3 million.[63] Losses intensified in 1991, although other economic factors such as strikes and high interest rates also played a part.

Stelco has followed the Japanese example in attempting to cope with the long-term decline in the steel market in industrialized economies by rationalizing operations, investing in technological upgrading, and diversifying into new businesses. For example, Stelco built its Lake Erie mill, a technologically advanced, low-cost integrated plant, to replace obsolete facilities. The plant is, however, one of the main reasons Stelco is nearly $1 billion in debt, and interest charges on this debt place a heavy burden on the company, particularly in a slumping market.

Stelco also moved into value-added manufacturing in an effort to flatten out the steelmaking cycles. In 1987, the company formed a joint venture with Jannock Ltd. and acquired a number of Jannock's steel-fabricating operations that serve the construction and agricultural markets. The business has not thrived, mainly because of the recession-related decline in construction, and the venture has contributed to Stelco's debt. The company has also tried to improve its product-development process, working with the Management of Technology Institute at McMaster University to develop a game plan to significantly reduce the risk associated with new-product development.

Stelco is now looking at further rationalization, concentrating on its most profitable products, selling assets, and decentralizing and flattening its management structures. Its financial situation, however, may prevent the company from investing in the R&D, capital expenditures, and new technologies it needs to enhance its competitiveness.[64]

Dofasco is also undergoing significant rationalization in the face of recession, major debt, and cash-flow problems at Algoma and a particular vulnerability to competition in its rail and structural operations. The scale of its financial problems leaves little room to invest in the technology needed to enhance competitiveness and ensure survival.

Both of these major integrated companies need to develop competitive strategies for each market segment and use those strategies to define their technology needs and decide whether to purchase the technologies or attempt to develop them in Canada. The potential for additional R&D investment may be limited to opportunities where there is a distinct likelihood of reasonable return on the R&D expenditure or the potential for considerable leverage of government funding support.

Opportunities and Growth Strategies

The rationalization that has taken place in the North American steel industry over the past decade, the increasing competition from low-cost producers, and the increasing use of substitute materials all suggest questions about what the steel industry might look like in the year 2000. Will there be an iron and steel sector as such, or will the steel industry be part of a materials sector that encompasses plastics, composites, and other new materials as well?

The Japanese steel sector has a strategic view in which steel becomes part of a larger materials industry. The strategy calls for restructuring of manufacturing operations and diversification of product lines.

The Japanese sector is restructuring to reduce its dependence on volume production for profit and is improving production efficiency through the use of flexible manufacturing systems and artificial intelligence. Large blast-furnace systems will still be needed for mass production, but smaller, more flexible steelmaking facilities (such as electric furnaces and smelting-reduction processes) will be used for lower volume, more specific requirements.

The Japanese sector is diversifying by placing more emphasis on the production of fine steels (which are higher value-added products and command higher prices) and by developing corrosion- and fire-resistant steels for potential new markets in the construction industry. The Japanese, like the Europeans, are also developing coatings for steel that insulate the material at high temperatures and prevent buckling. Other research is directed at developing vibration-damping sheet steel for use in car bodies and road construction; corrosion-resistant steels for offshore oil and gas exploration; and lightweight, high-strength steels and composites for space exploration.

Through research into new types of steel, and new processes to improve the qualities of mass-market steels, the Japanese steel industry is preparing for next-generation steelmaking. At the same time, it recognizes that demand for steel is declining and that it must be ready to participate in the production of new materials that will replace steel.

Has the Canadian steel industry a similar vision of the future and its place in it? What role is there for R&D? What sort of technology strategies will ensure that the leading steel companies remain competitive into the next century?

The Canadian integrated steel producers know that if they are to survive without being subject to foreign takeover, they can no longer afford to cater solely to their traditional markets, as these are declining. The mini-mill operators that serve smaller, regional markets are in a better position to survive, as long as they can produce the quality and types of steel demanded by their customers. Some may attract foreign investment to help upgrade technology; such is the case with Atlas Stainless Steel in Tracy, Quebec, which is benefiting from South Korean investment. Other firms, such as Co-Steel Inc., based in Whitby, Ontario, and Ipsco, in Regina, Saskatchewan, may make further foreign acquisitions or investments to support their successful geographic diversification.

If Canadian steel companies are to produce more specialty steels, they will need to identify potential customers and work closely with these customers to develop the kinds of steels they require. Small opportunities probably exist for steels for cold-weather and arctic construction, offshore structures, telecommunications and other high-tech industries. Specialty-steel manufacturers will need to invest in new technologies, such as flexible manufacturing systems, and spend considerable funds on R&D to develop products for specific requirements. Cash flow to support the necessary capital expenditures and R&D investment clearly poses problems.

Canadian companies will be hard pressed to follow the lead of their Japanese counterparts and start viewing the steel industry as part of a larger materials industry, one that must integrate forward to add value and profits. Unlike Japanese steel companies, Canadian firms cannot use the steel business to finance substantial materials research and product development. Such R&D would require huge capital investment in new technology, as well as different management expertise and even commitment from unionized workers, to ensure potential productivity gains are achieved from the sale of new, advanced materials. Research resources would have to be channelled into new-materials research, perhaps using Canada's abundant natural resources, to develop composites, including steel composites, and other materials such as plastics or ceramics for customers prepared to work closely with the steel companies.

An alternative approach might be cooperative ventures with companies producing non-steel materials. There might be merit in promoting cooperative research targeted at applied processes and products, such as auto parts, when the cooperative partner has the financial resources to underwrite the research.

If the Canadian steel industry is to perform more R&D and make any significant attempt to develop leapfrog technologies, it will almost certainly require large partners or substantial support from government. To enhance its chances for government support and other private-sector funding, the industry will need to establish a strong R&D proposal, bringing together many suppliers, customers, universities, and perhaps even governments in a major consortium. The industry could address this challenge through CSIRA.

It has been said of the management of the big U.S. steel firms, when they seemed reluctant to bet money on inventions, that "they tried to avert risk, and in trying to avert risk they took huge unacknowledged risks."[65] Canadian management should not expose itself to similar criticism in the 1990s.

Appendix: Framework for Technology Strategies

As part of the methodology for analysing each sector, the Science Council of Canada sought whenever possible to assess company technology strategies according to the following framework:

	adopt and adapt	innovation	breakthrough
product			
process			

Strategy Classes

Adopt and Adapt: Acquire a technology and adapt it to serve as a competitive platform.

Innovation: Incrementally improve on winning technology to get greater market share or maintain competitive edge.

Breakthrough: Seek to create a discontinuity in the marketplace, thereby leaping ahead of the competition.

The company case studies generally looked for at least seven key dynamics influencing a company's technology strategy:

- three internal dynamics:
  - competitive position,
  - capacity for innovation, and
  - strategy and vision; and
- four external dynamics:
  - customer demands,
  - competitive rivalry,
  - supply condition, and
  - available technology.

The methodology also incorporated essentially a three-step process for each sector. In the first step one or more contractors analysed the main elements in the competitive and R&D performance of the Canadian sector and its leading foreign competitors. The second step included evaluation of the contract report(s), discussion with contractors and other experts, additional in-house research, and preparation of a draft Council report. In the third step, external reviewers commented on one or more drafts of the Council report, which were then revised and refined as required, drawing on the advice of the liaison person for that sector on the Steering Committee (see Acknowledgements). For some sectors, the third step also involved several external reviewers in a small workshop, one part of which

helped define some elements of a potential action plan for the sector. The report was then submitted for final approval to the Executive Committee of the Science Council, before being forwarded to Industry, Science and Technology Canada.

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